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United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: October 3, 1997

TO : Dale Ray
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THOUGH: for Andrew G. Stadnik, AED Engineering Sciences NVM
Nicholas V. Marchica, Director, Mechanical Engineering NVM

FROM : Rikki Khanna
Fire Protection Engineer
Directorate for Engineering Sciences

SUBJECT: Transmittal of documents: Draft Standard, Technical Basis Document, and Response to ANPR Comments

This memorandum forwards the subject documents for the Upholstered Furniture Project.

Attachment(s)

Draft Standard
Technical Basis Document
Response to ANPR Comments

DRAFT STANDARD FOR UPHOLSTERED FURNITURE

Standard for Small Open Flame Ignition Resistance of Upholstered Furniture

Subpart A - The Standard

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§ 1 Purpose, Scope and Applicability

(a) *Purpose.* This draft standard prescribes requirements for testing small open flame ignition resistance of upholstered furniture before the sale in commerce or the introduction in commerce of any upholstered furniture which is subject to the standard. The standard prescribes test methods to determine the flammability performance of the upholstered furniture seating area in § 8 and dust cover in § 9 when exposed to a small open flame.

(b) *Scope.* All upholstered furniture, as defined in § 3 manufactured or imported after the effective date of this standard are subject to requirements of this standard.

(c) *Applicability.* The requirements for testing prescribed by this standard are applicable to each "manufacturer" as that term is defined in § 3 of upholstered furniture or its components, that are manufactured for sale in commerce.

§ 2 Referenced Documents

(a) BS 5852: Fire Tests for Furniture, Part 2, British Standards Institute - 1982.

§ 3 Definitions

In additions to the definitions given in Section 2 of the Flammable Fabrics Act as amended (15 U.S.C. 1191), the following definitions apply for the purposes of this standard.

Afterflame The time for which a material continues to produce a visible flame after the ignition source has been removed.
Afterglow The time for which a material continues to glow after the removal of an external ignition source and after the cessation of flaming of the material.
Barrier A material that is intended to reduce the ignitability of upholstery.
Combustion An exothermic, self-sustaining reaction involving a solid or liquid, and or gas phase fuel. It can occur through flaming, glowing or smoldering.
Cover Fabric The outermost layer of fabric or related material used to enclose the main support system and upholstery filling used in the furniture item.
Dust Cover The outermost layer of non-structural material on the underside of the finished item of upholstered furniture.
Glow Combustion characterized by incandescence, without visible flame.
Ignition Initiation of combustion. It is perceived by the presence of any visible flaming, glowing, or smoldering after removal of the test flame.
Manufacturer An individual plant or factory at which upholstered furniture and/or it's components are produced or assembled.
Seating Area The intersection of the vertical and horizontal surfaces of upholstered furniture that are intended for seating purposes.
Self-Extinguishment The termination of any visible combustion within 2 minutes

of the test flame removal before the specimen is consumed.
Small Open-Flame A flaming ignition source that simulates the heat output of a match, candle, or cigarette lighter.
Smolder Combustion characterized by smoke production, without visible flame or glowing.
Specimen A specific portion of a material or a laboratory sample upon which a test is performed.
Upholstered Furniture A unit of interior furnishing with a resilient surface covered, in whole or in part, with fabric or related material, that is intended for use or may be expected to be used in homes, and is intended or promoted for sitting or reclining upon.

§ 4 General Requirements

(a) *Summary of test method.* The test method measures the ability of upholstered furniture to resist ignition when subjected to a small open-flame source (e.g. match, candle, or cigarette lighter). The surfaces to be tested are the seat/back or side intersection of the seating area and the dust cover. Materials used in upholstered furniture seating area construction are to be tested by constructing a small scale mock-up consisting of a cover fabric, any barrier materials used in the finished item between the cover fabric and filling, and standard polyurethane foam.

Dust cover materials are to be tested as individual components. Passing dust covers that do not melt or split when tested in accordance with § 9 can be used in any furniture construction of the assembled product. Interior materials within 1 inch (25.4 mm) measured vertically of a passing dust cover material that are exposed if the dust cover melts or splits, must also be tested in accordance with § 9 and pass.

The manufacturer has the option of constructing the seating area mock-up with the actual filling materials used in the finished product instead of the standard foam.

(b) *Criteria for Seating Area Test.* When testing the seating area mock-up in accordance with § 8, the test sample passes if:

i. All three specimens cease all modes of combustion within two minutes after flame removal.
ii. Any form of combustion does not extend to any edge of the mock-up.

(c) *Criteria for Dust Cover Test.* When testing the dust cover mock-up in accordance with § 9, the test sample passes if:

i. All three specimens cease all modes of combustion within two minutes after flame removal.
ii. Any form of combustion does not extend to any edge of the specimen.

§ 5 Test Apparatus

(a) Specimen Holders and Frame: The specimen holders consist of metal frames used to mount the test specimens in the test fixture.

Specimen Holders and Mock-up Frame Dimensions

Test Location	Length/Height Max/Min	Width Max/Min	Depth Max/Min
Dust Cover	10.1 in (257 mm) 9.9 in (251 mm)	10.1 in (257 mm) 9.9 in (251 mm)	N/A
Seating Area Back Frame[1]	11.9 in (302 mm) 11.7 in (297 mm)	17.8 in (452 mm) 17.6 in (447 mm)	N/A
Seating Area Base Frame[1]	N/A	17.8 in (452 mm) 17.6 in (447 mm)	6.0 in (152 mm) 5.8 in (147 mm)

1 Seating Area Mock-up frame is based in BS 5852, 1979.

(b) Seating Area Mock-up: The test frame shall consist of two rectangular frames hinged together and capable of locking at a right angle to each other. The frames shall be made of 1 in. x 1 in. (25 mm x 25 mm) steel angle 1/8 in. (3 mm) thick, and shall securely hold platforms of steel mesh set 0.25 ± 0.05 in. (6 ± 1 mm) below the front face of each test frame.

(c) Clips: Clips are used to secure the specimens to the holders.

(d) Gas: The gas shall be C.P. Grade, 99.0 % purity.)

(e) Burner : Two burner tubes which consists of stainless steel tube with the following dimensions:

Burner Tube Dimensions

Test Location	Inside Diameter. Max/Min	Outside Diameter Max/Min	Length Max/Min
Dust Cover	0.239 in (6.07 mm) 0.235 in (5.97 mm)	0.317 in (8.05 mm) 0.307 in (7.80 mm)	6.05 in (154 mm) 5.95 in (151 mm)
Seating Area	0.239 in (6.07 mm) 0.235 in (5.97 mm)	0.317 in (8.05 mm) 0.307 in (7.80 mm)	11.05 in (154 mm) 10.95 in (151 mm)

The burner tubes are connected by flexible tubing to a cylinder containing butane gas.

(f) Gas Supply System: Consists of a pressure gage, flowmeter, fine control valve, and cylinder regulator providing an outlet pressure of 2.75 kPa (0.4 psi). The flowmeter shall be calibrated to supply the butane gas at a rate of 45 ± 2 ml/min (2.75 in^3/min) at 25° C (77° F). Under the above conditions, the burner should produce a flame approximately 35 mm (1.4 in) in height.

(g) Gas Flow Control: It is essential that the gas flow rate to the burner complies with the flow rate specified. Some difficulties have been reported with the supply and measurement of the gas, particularly where the gas cylinder has to be stored in an environment cooler than the defined test conditions and/or some distance from the test specimen.

(h) Test Fixture: A test fixture fabricated in accordance with the requirements of Appendix B shall be used to deliver the test flame to the samples. See **Figure 1**.

§ 6 Atmospheres for Conditioning and Testing

(a) Test Enclosure: The test enclosure shall consist of either a room with a volume greater than 20 m^3 (706 ft^3) (which contains adequate air for testing), or a smaller enclosure with adequate airflow. Inlet and extraction systems shall provide an air flow rate of less than 0.2 m/s (.66 ft/s) in the proximity of the test specimen to provide adequate air without disturbing burning behavior.

(b) Water Soak Procedure: This procedure shall be performed prior to conducting the seating area test in § 8. The intent of the Water Soak Procedure is to remove any nondurable fire retardant finishes used in cover fabric samples that may be affected by exposure to water. A specimen of the seating area cover fabric is to be totally submerged in 1 gallon (3.2 liters) of tap water at room temperature for 24 hours.

i. The cover fabric specimen is to be placed in a container of sufficient size to completely submerge the cover fabric sample.

ii. After the immersion period, the sample is to be thoroughly air dried and conditioned per § 6 (c).

(c) Conditioning : The specimens to be tested shall be conditioned for at least 24 hours immediately before the tests in the following atmosphere:
- Temperature: 25 ± 2° C (77 ± 6° F)
- Relative Humidity: 40 - 55 %

(d) Testing Initiation: The test shall be performed in an atmosphere having a temperature between 10° - 30° C (50° - 86° F) and a relative humidity between 20% to 70%. If the test room does not meet the conditions of § 6(c), then testing shall be initiated within **10 minutes** after the specimens are removed from the conditioning room. Otherwise recondition samples per Section § 6(c).

§ 7 Test Sample Preparation

1. Seating Area Samples: The sample materials should be removed from any packaging prior to conditioning. The test materials shall be the cover fabric and any barrier materials (if applicable) used in the finished product and standard polyurethane foam as the filling material. A specimen of the seating area mock-up is described below. A seating area sample consists of three specimens.

   Cover Fabric and Barrier Materials The cover fabric and barrier material size needed for each test is 40 ± 0.2 in (1016 ± 5 mm) x 27.5 ± 0.2 in (699 ± 5 mm). The cover fabric (and any barrier material) specimens shall have triangular cut-outs 22.5 in (572 mm) from one end on both sides. The size of these cut-outs shall be approximately 2.1 ± 0.2 in (55 ± 5 mm) x 5.25 ± 0.2 in (140 ±5 mm) high. See **Figure 2**.

   (a) Foam* Two pieces, one 18.0 ± 0.2 in x 11.75 ± 0.2 in x 3.0 ± 0.2 in (458 ± 5 mm x 305 ± 5 mm x 76 ± 5 mm) thick, and the other (18.0 ± .2 in x 3.25 ±.2 in x 3.5 ± .2 in (458 ± 5 mm x 83 ± 5 mm 76 ± 5 mm) thick are required for each test. The foam shall be polyether type non-FR polyurethane with a density of 1.5 to 1.8 lb/ft^3 and firmness of 25-30 IFD. See **Figure 3**.

   (b) Position seat mock-up in the upright position. Insert end of cover fabric (and any barrier material) such that the larger 22.5 in (572 mm) dimension of the material is placed on the vertical (back) portion of the seat mock-up.
   Next, insert the smaller 17.5 in (445 mm) dimension of the fabric (and any barrier material) from behind around the hinged bar. Both fabric (and any barrier) ends shall be pulled taught and laid across the horizontal seating surface.

   (c) Place larger foam against crevice and on top of horizontally placed fabric (and any barrier material), and the vertical back of the seat mock-up.

   (d) Wrap the larger dimension fabric (and any barrier material) around the foam to the back of the seat mock-up and fasten with metal clips.

   (e) Position smaller dimension of fabric (and any barrier material) and place smaller foam flush on front edge of seat frame with 75 mm

*As stated in **§ 4** the manufacturer has the option of constructing the seating area mock-up with the actual filling materials used in the finished product instead of the standard foam.

(17.7 in) dimension vertical. Wrap both fabrics around entire contour of seat foam. Insert larger foam between the wrapped fabric and the vertical back of the seat mock-up.

(f) Fasten all fabric edges (and any barrier material) to the top, bottom, and sides of each frame using metal clips. Ensure that the fabric is secured and under even tension. Pull fabric taught to eliminate air pockets between fabric and foam, but do not create a gap larger than 1/8" along the crevice. See **Figure 4**.

2. Dust Cover Material Samples: The dust cover materials should be removed from any packaging prior to conditioning. One specimen measuring no less than 12 ± 0.2 in x 12 ± 0.2 in (305 ± 5 mm x 305 ± 5 cm) should be used for each dust cover test. A test sample consists of three specimens. See **Figure 5**.
   (a) Secure dust cover sample with metal clips in the specimen holder to avoid wrinkles in the fabric. Pull sample taught around the edges to avoid any dipping or sagging. See **Figure 6**.

§ 8 Seating Area Test Procedure

1. Sample Positioning

   (a) Install the seat mock-up on the test fixture rails, align and adjust such that the horizontal burner tube rests evenly along the vertical and horizontal intersection of the crevice. See **Figure 7**.

2. Ignition Source Application:

   (a) Light the gas emerging from the longer 11 in (279 mm) burner tube, adjust the gas flow rate (specified in § 5) and allow the flame to stabilize for at least 2 minutes. (Ensure the flame height is approximately 35 mm (1.4 in)
   (b) Actuate the Furniture Flammability Fixture(FFF) to apply the lit burner tube axially along the crevice between the seat and back for **20 seconds**. The flame shall not be less than 2.1 in (50 mm) from the nearest side edge.
   (c) Repeat the Seating Area Test on the remaining two specimens.

3. Test Observations:

Record the following observations for 2 minutes after the test flame is removed:

(a) Record the ignition/non-ignition of the mock-up
(b) Record the afterflame, afterglow, and smolder time of the mock-up
(Note: If the flaming progresses to top or any other edge of the sample within 2 minutes, stop the test, and record "failure")
(c) Record Self Extinguishment (Yes/No)

§ 9 Dust Cover Test Procedure

1. Sample Positioning

(a) Place the specimen horizontally in its holder in the FFF and adjust the burner tube by placing the 35 mm flame gage on the tube, until the tip of the gages touches the center of the dust cover specimen. See **Figure 8**.

2. Ignition Source Application:

(a) Light the gas emerging from the shorter 152 mm (6.0 in) burner tube, adjust the gas flow rate (specified in § 5) and allow the flame to stabilize for at least 2 minutes. Ensure the flame height is approximately 35 mm (1.4 in).
(b) Actuate the FFF to apply the vertically lit burner flame at the bottom center of the specimen for **20 seconds**.

(c) Repeat dust cover test on the remaining two specimens.

3. Test Observations

Record the following observations for 2 minutes after the test flame is removed:

(a) Record the ignition/non-ignition of the dust cover
(b) Record the afterflame, afterglow, and smolder time of the dust cover specimen.
(Note: If the flaming progresses to any edge of the sample within 2 minutes, stop the test, and record "failure")
(c) Record the presence of any dripping of dust cover material
(d) Record Self Extinguishment (Yes/No)

APPENDIX A-Solving Gas Flow Problems

The rate of butane gas flow to the burner tube must conform to the specified flow rate. Any deviation from the specified rate will affect the heat energy imparted to the test specimen. Difficulties can occur with the supply and measurement of butane when either the cylinder is stored in an environment cooler than defined test conditions or when greater than 10 feet distance exists from the test fixture. In such cases, a 5 to 10 feet maximum length of tubing between the FFF and tank both inside the controlled environment (15 - 30° C (50 - 86° F) can help the butane gas to stay in equilibrium. Otherwise flowing butane through a length of metal tubing immersed in a water bath maintained at 25° C (77° F) is adequate so that the flow can correct for temperature variations.

Accurate setting and measurement of the butane flow rate is also essential. A digital reading flow meter needs to be checked when initially installed, and also at regular intervals during testing. One method capable of measuring the absolute butane flow at the burner tube is accomplished by . This can be done by connecting the burner tube with a short length of tubing (about 7 ID mm (.276 in)) to a soap bubble flow meter. The upward passage of a soap film meniscus in a glass tube of calibrated volume (e.g. a burette) over a know period of time gives an absolute measurement of the flow. Fine control valves which can each be preset to one of the desired butane flow rates, with simple switching means from one to the other are helpful.

APPENDIX B Furniture Flammability Fixture Construction Drawings

APPENDIX C Figures

Figure 1 - Test Fixture

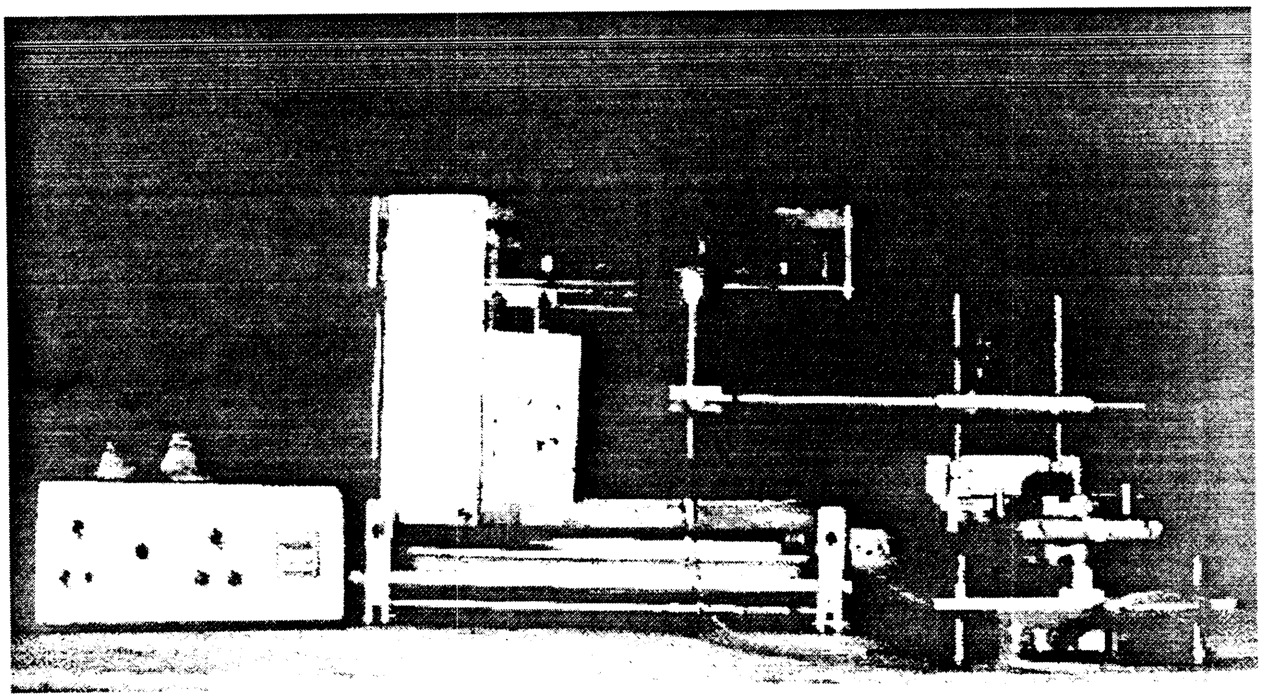


Figure 2 - Cover Fabric/Barrier Material Specimen

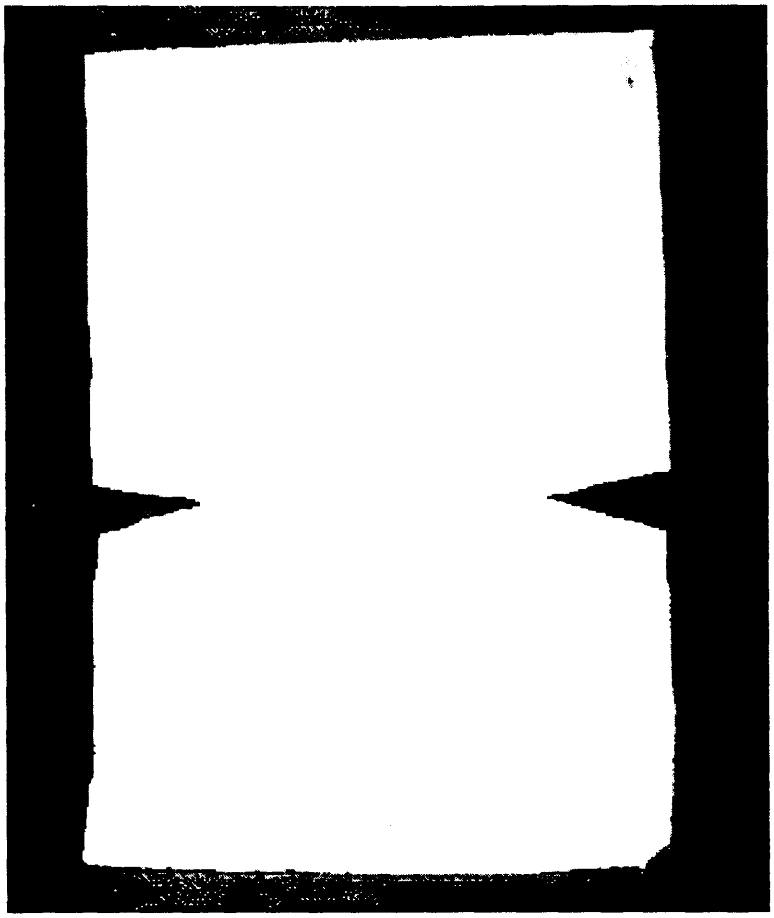


Figure 3 - Foam Specimens

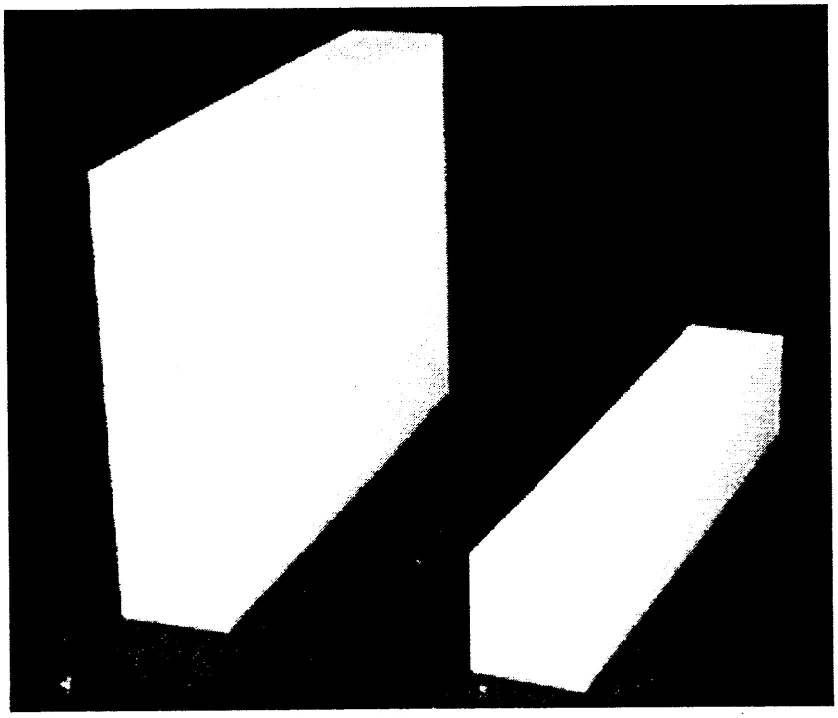


Figure - 4 Seating Area Mock-Up

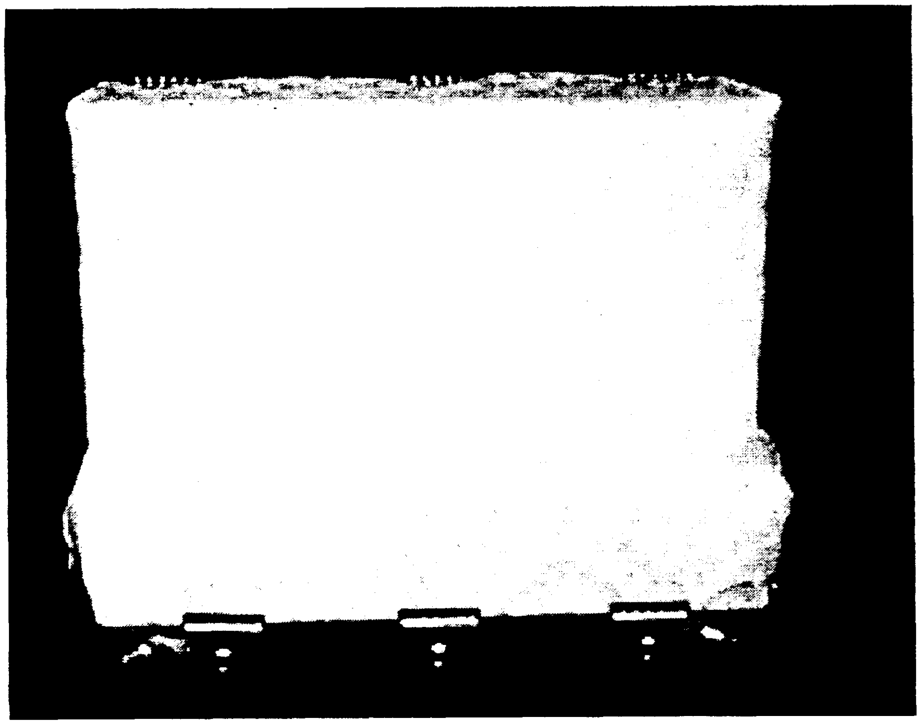


Figure - 5 Dust Cover Specimen

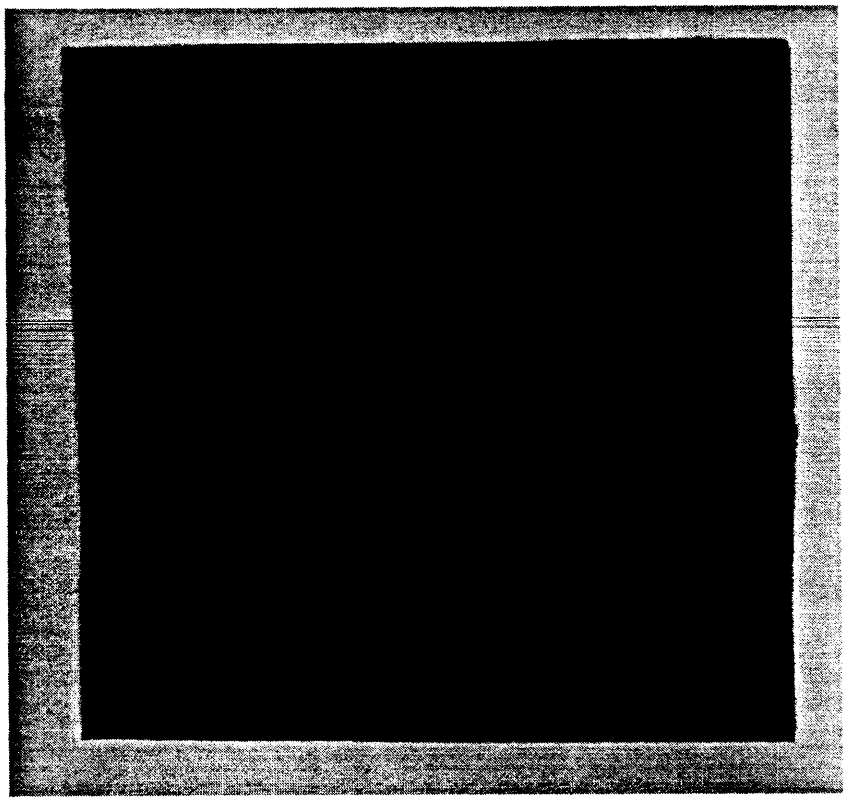


Figure 6 - Dust Cover Specimen in Holder

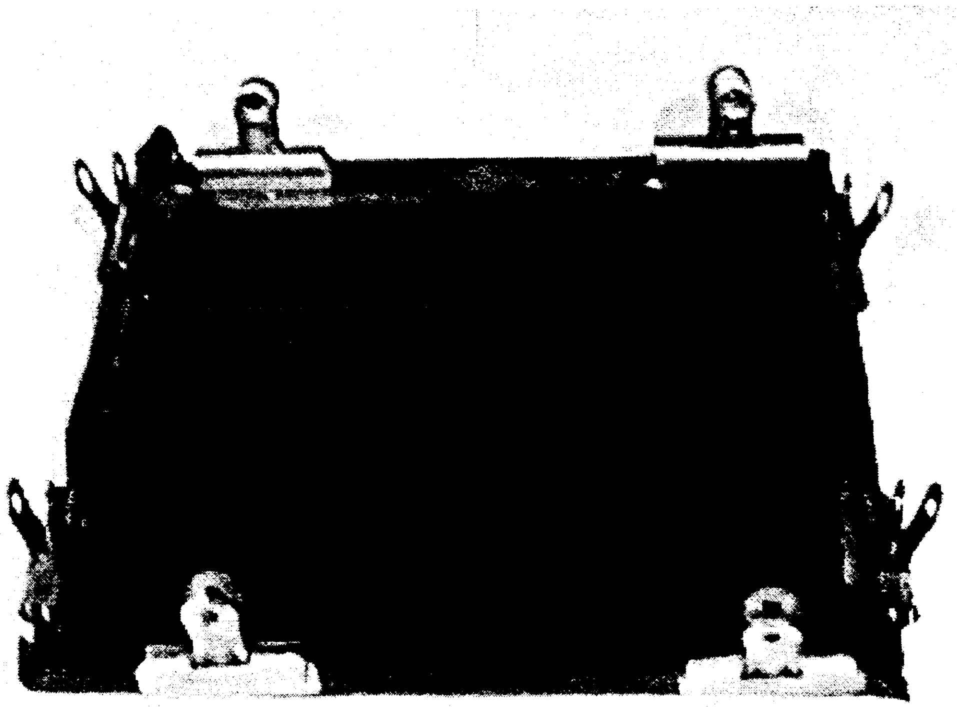


Figure 7 Seating Area Mock-Up Positioned in Test Fixture

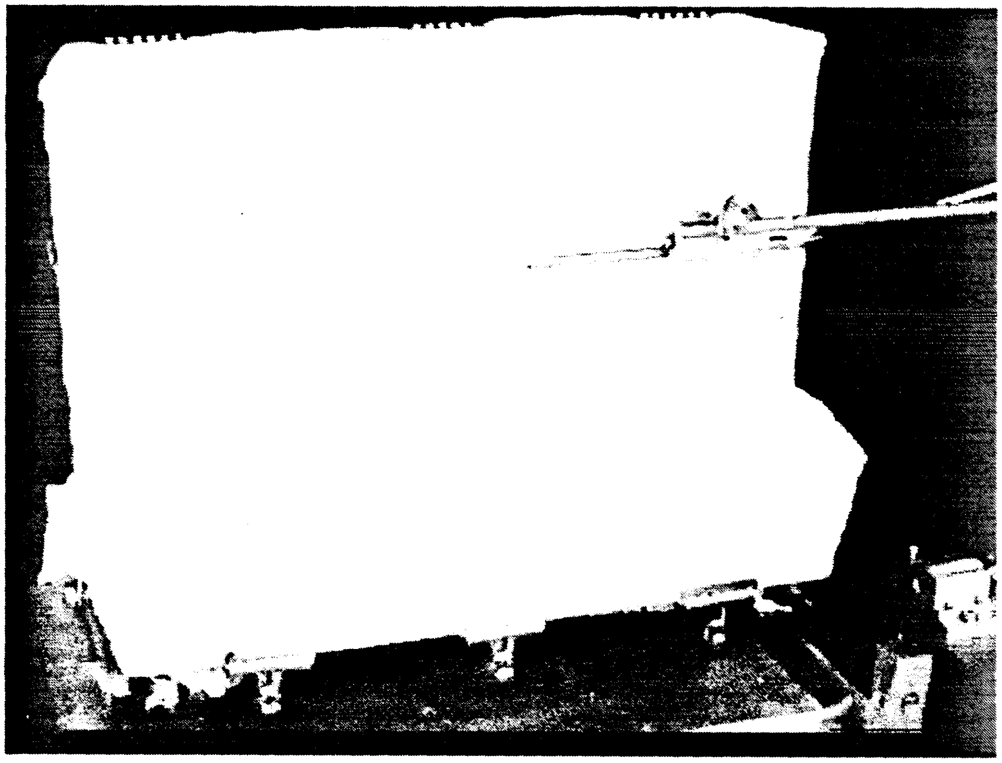
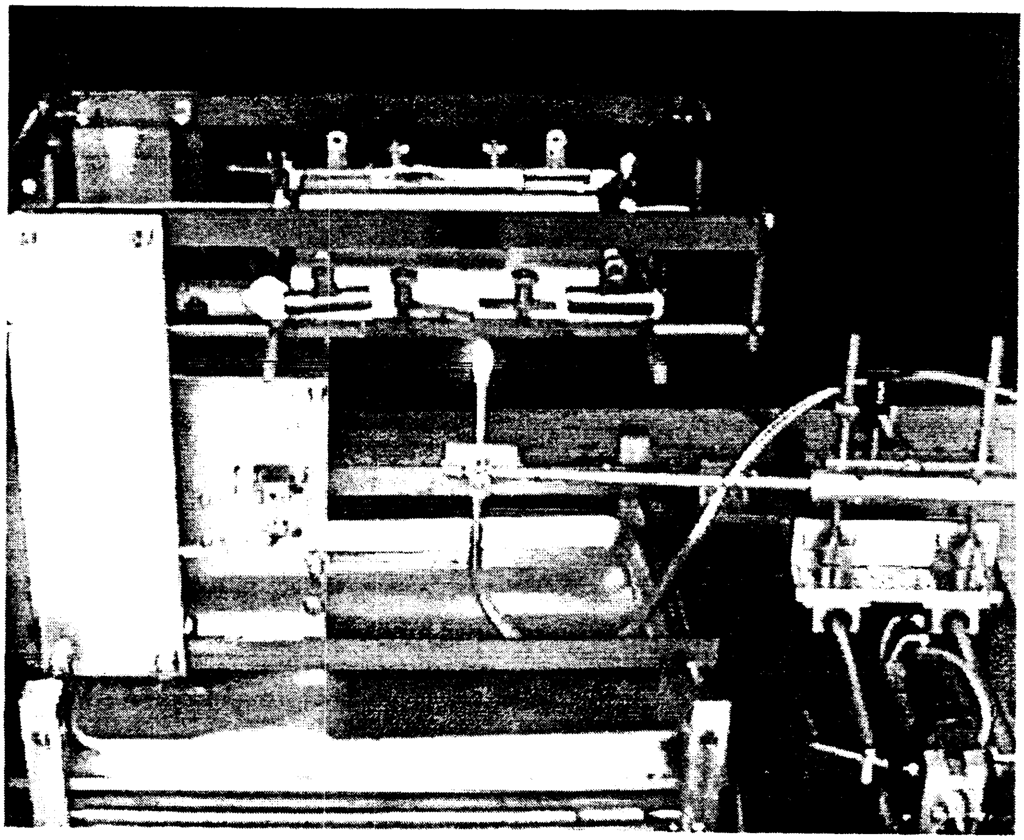


Figure 8 - Dust Cover Positioned in Test Fixture



10/10/97

Technical Basis Report for the Draft Performance Standard for the Flammability of Upholstered Furniture

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2. Average 35 mm Butane Flame Temperatures

Abstract

1. Introduction
2. Standard Approach
3. Scope of Standard
4. CPSC Flammability Apparatus and Test Method
5. Acceptance Criteria

TECHNICAL BASIS FOR THE DRAFT STANDARD FOR THE FLAMMABILITY OF UPHOLSTERED FURNITURE

ABSTRACT

On June 1994, the Commission granted a petition from the National Association of State Fire Marshals, and began the development of a performance standard for small open flame ignition of upholstered furniture. This report discusses the rationale for the technical approach of the performance test method, the experimental set-up for the test method, and other requirements of the draft standard. Mock-ups of two test locations of upholstered furniture, the seating area and dust cover are subjected to a standard test flame for a set duration and orientation. The acceptance criteria involves measurements of continued combustion and flame progression on the specimen over time after removal of the ignition source.

The performance test provisions in the draft standard were derived from (1) a comprehensive testing program including full scale and mock-up specimens representing a range of flammability performance, (2) a review of actual small open flame upholstered furniture fire incidents (3) quantification of flame characteristics of known ignition sources and, (4) test fixture testing to assess the practicability of the standard. These provisions address the risk of deaths and injuries resulting from accidental small open-flame upholstered furniture fires. This report summarizes the technical basis for the standard.

1.0 INTRODUCTION

This report by the Consumer Product Safety Commission (CPSC) staff describes the technical basis of a draft upholstered furniture flammability standard. The draft standard is intended to address the risks presented by the small open flame ignition of upholstered furniture.

The CPSC draft standard was developed using the British Standard, "BS 5852, Fire Tests for Upholstered Furniture, Part 2", as a basis with additional input from laboratory studies, field investigations, meetings, and comments from interested parties. Presentations were made to various industrial groups representing the fiber, textile, and upholstered furniture industries. CPSC personnel have also visited textile and furniture manufacturing facilities. All suggestions have been considered in the development of the apparatus, test method, acceptance criteria, and other provisions in the draft standard.

2.0 SCOPE OF COVERAGE

The scope of the draft standard is limited to residential upholstered furniture items that present an unreasonable risk of death or injury from ignition by small open flames that may come in contact with such items in an inadvertent manner such as from fire play by young children and accidental dropping of small open flame sources by older persons. The applicable products are identified as:

•Chairs and sofas or other furniture intended for seating with upholstered seats and backs or sides manufactured or imported after the effective date of the standard

•Items with dust covers - any fabric or other nonstructural material attached to keep dirt/dust from accumulating in the item's interior

• Non-rigid seating items which may be formed with seating and back support, such as bean bag chairs

•Office furniture intended for sale or use by consumers

The following products are not within the scope of the draft standard:

•Items without both upholstered horizontal seating surfaces and upholstered sides or backs

•Items without both cover upholstery and filling material

•Non-residential or contract furniture

•Futons, futon covers and slipcovers

•Mattresses and bedding

•Outdoor furniture

3.0 STANDARD APPROACH

3.1 Open Flame Ignition Prevention

The CPSC staff's draft standard is based on preventing sustained combustion of upholstered furniture resulting from small open flame exposure. National fire data[1] for 1994 show that open flame ignition of upholstered furniture results in 3,800 fires, 540 injuries, and 160 deaths when furniture is the first item ignited. Of these, small open flame sources were responsible for 460 injuries and 100 deaths. The draft standard is intended to lessen the likelihood of those fires in which upholstered furniture is the first item ignited. If the sustained combustion of upholstered furniture is prevented, flames will be unlikely to produce sufficient heat to ignite nearby combustibles or generate toxic smoke.

Analysis of the national fire data[2] shows that a majority of the fire incidents in the scope of the project involved childplay with matches and cigarette lighters as the primary cause of small open flame upholstered furniture fires. An effective approach to address this fire scenario is to prevent sustained combustion of upholstered furniture by requiring that the upholstery fabrics not support combustion after exposure to a small open flame source. This should reduce the likelihood of ignition and the transition from ignition to the initiation of sustained combustion of the upholstered item. This approach would decrease the number of fires caused by childplay or other activities where matches or cigarette lighters are the ignition source.

[1] "1994 Residential Fire Loss Estimates", Directorate for Epidemiology and Health Sciences
[2] "Small Open Flame Ignitions of Upholstered Furniture", Final Report, Directorate for Epidemiology and Health Sciences, September 1997

3.2 Alternate Approach

An alternate approach considered by CPSC staff to address upholstered furniture flammability is to apply heat release rate requirements to furniture. The heat release rate is the rate at which energy is liberated during combustion. The heat release rate approach is predicated on the theory that by limiting the heat release from combustibles, one can limit rapid fire growth and provide more escape time for occupants prior to reaching **untenable** conditions. By limiting the heat release rate of materials, a fire involving these materials may develop more slowly, allowing more escape time for occupants, and possibly preventing **flashover conditions**. On this basis, the Model Building Codes have adopted heat release requirements for building materials and furnishings for high-risk occupancies.

3.3 Basis for CPSC Approach

CPSC staff feels that controlling the heat release rate is not the most effective method of reducing the risk of death and injury from ignition of furniture in a residential fire scenario. In fires, many deaths or serious injuries can result from incapacitation due to toxic combustion products inhalation. Controlling heat release rates does not prevent the generation of toxic combustion products that can present serious life safety concerns in upholstered furniture fires. Heat release rate requirements are most relevant to high risk occupancies where fire protection systems (i.e. fire sprinklers, fire alarms) are installed to provide additional safety in the form of slow fire growth. For residential applications, preventing sustained combustion of upholstered furniture is more likely to prevent deaths and injuries and would obviate the need for addressing smoke toxicity, rapid heat release, or other factors. Therefore, CPSC staff believes adoption of heat release requirements would not reduce fire fatalities as effectively as a standard that lessens the likelihood of ignition of upholstered furniture in residential fire scenarios.

Existing flammability standards that apply a similar approach have been successful. Examples of such standards include the voluntary Upholstered Furniture Action Council Program, Standard for the Flammability of Mattresses and Mattress Pads (FF 4-72), Standard for the Flammability of Children's Sleepwear (FF 5-74), and BS 5852 Fire Tests for Upholstered Furniture.

Untenable conditions- when the temperatures and smoke concentrations reach levels that are unacceptable for life safety

Flashover - stage of a fire when the enclosure becomes fully involved and all combustibles in the enclosure ignite.

4.0 TEST METHOD AND APPARATUS

The parameters of the test method were chosen to combine simulation of real-life upholstered furniture fires using a reasonable, repeatable, and concise laboratory test method. The CPSC staff's test method is based on the match flame test of the BS 5852 Fire Tests for Furniture Standard, and input from field data of small open flame upholstered furniture fires. Two significant differences in the CPSC draft sandard and the BS 5852 Standard are the addition of the dust cover test and use of a mechanized apparatus to provide consistent flame delivery to the test specimens. The Field data[2] show that besides the seating area, the dust cover location was the most common location involved in upholstered furniture fires.

In order to reliably characterize **full scale** flammability behavior of furniture, the test method applies a furniture mock-up **bench scale** approach, where the upholstery fabric and any fire resistant barrier materials to be used in the finished product are tested in combination with a standard foam filling material. The fabric and barrier material over standard foam approach was chosen due to testing[3] showing that commonly used filling materials had virtually no effect on the ability of furniture to limit combustion resulting from small open flame exposure. The study also concluded that cover fabrics are the primary determinant of ignition performance. Therefore it would obviate the need to evaluate the contribution of filling materials in the test approach.

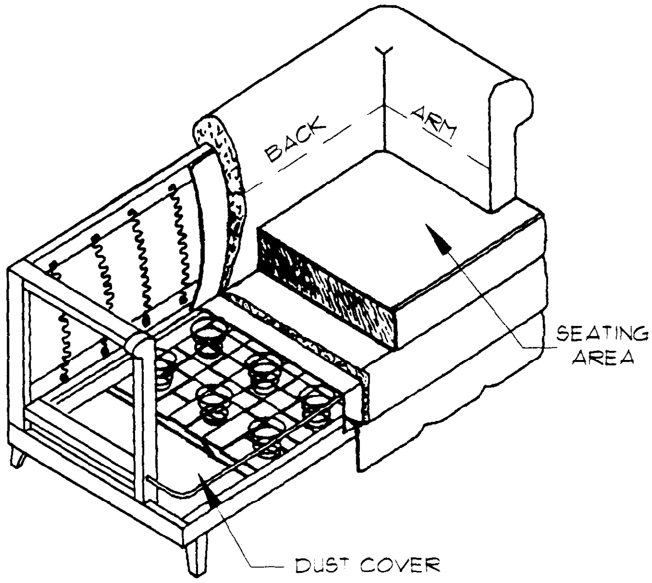
Staff recognizes that a full scale test may be more representative of the actual product performance. However, the mock-up bench scale approach reasonably represents ignition performance of finished products since the cover fabric was concluded to be the primary determinant of ignition. In addition, the mock-up bench scale approach will reduce the economic impact of a flammability standard on industry. The work leading to the major parameter choices is described in this report.

4.1 Test Locations

The two test locations were chosen from information obtained from actual fire incidents involving upholstered furniture. Most of the small open flame upholstered furniture fires resulted from childplay with matches or cigarette lighters. In-depth investigations[2] revealed the most prominent locations where ignitions of upholstered furniture were most likely to occur: the seating area and to a lesser extent, dust cover. These locations are shown in Figure 1. Small scale mock-ups of the two identified ignition locations are made for testing purposes.

bench scale- a test method in which the smaller scale mock-up of the end-product is evaluated.
full scale- a test method in which the end-product or full size mock-up of the product is evaluated.
3 - Upholstered Furniture Flammability Testing: Full Scale Open Flame Data Analysis, February 26, 1996

Figure 1 : Potential Open Flame Ignition Locations Identified in Field Study



4.2 Specimens

4.2.1 Seating Area

Data from fire incidents[2] support that the seating area is the portion of upholstered furniture where ignition is most likely to occur. The seating area test evaluates fire performance in a vertical/planar intersection test geometry which represents the seat/back and seat/arm junction of finished upholstered items. The test flame is delivered to the crevice via the CPSC Furniture Flammability Fixture. Consideration was given to selecting the flat seat cushion as the test location, however, a flat cushion would not account for the upward flame spread that may occur if the back of the chair is ignited. The crevice location allows for the evaluation of both the seat/back and seat/arm locations shown in Figure 1.

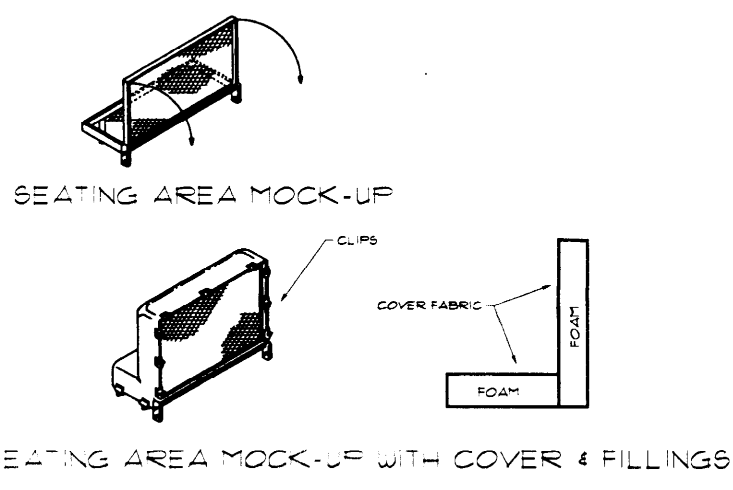
The seating area mock-up, shown in Figure 2, consists of two metal frames hinged and locked at right angles, upholstery/filling materials, and any barrier or lining materials intended to impart fire resistance used in the actual construction of the chair. The seating area specimen size and configuration were chosen to represent a small-scale mock-up of the geometry typical of an upholstered furniture seating area. The seating area mock-up is similar to the test frame used in the BS 5852 Standard. The CPSC test method varies slightly from the BS 5852 mock-up in that the way the seating area mock-up is assembled such that the crevice is more reflective of actual furniture. Staff recognizes that the BS 5852 seat mock-up approach is a simplified geometry of the finished item seating area and this approach seems reasonable since there is too much variation in upholstered seating constructions to address every possible geometry.

Prior to testing, the top surface of seating area fabric samples are subjected to a soaking procedure to ensure any fire retardant treatments are not compromised when exposed to water or normal wear which may occur during use of the product.

The General Requirements of the draft standard limit the allowable combustion time and flame spread on the sample. These requirements are intended to lessen the likelihood of small open flame ignited fires originating in the seating area of upholstered furniture. Details on the selection of requirements and acceptance criteria are discussed later in this report.

Laboratory testing[4] has demonstrated that the technology is available to meet the requirements of the Seating Area Test. These include the use of naturally flame resistant fabrics, chemical flame retardant fabrics treatments or backcoating, and use of fire resistant barriers. Either one or combination of these technologies can be used to meet the requirement of the draft standard.

Figure 2: Seating Area Mock-Up



4 - Memorandum from Linda Fansler to Dale Ray, "Summary of Upholstered Furniture Tests", October 10, 1997

4.2.2 Dust Cover Test

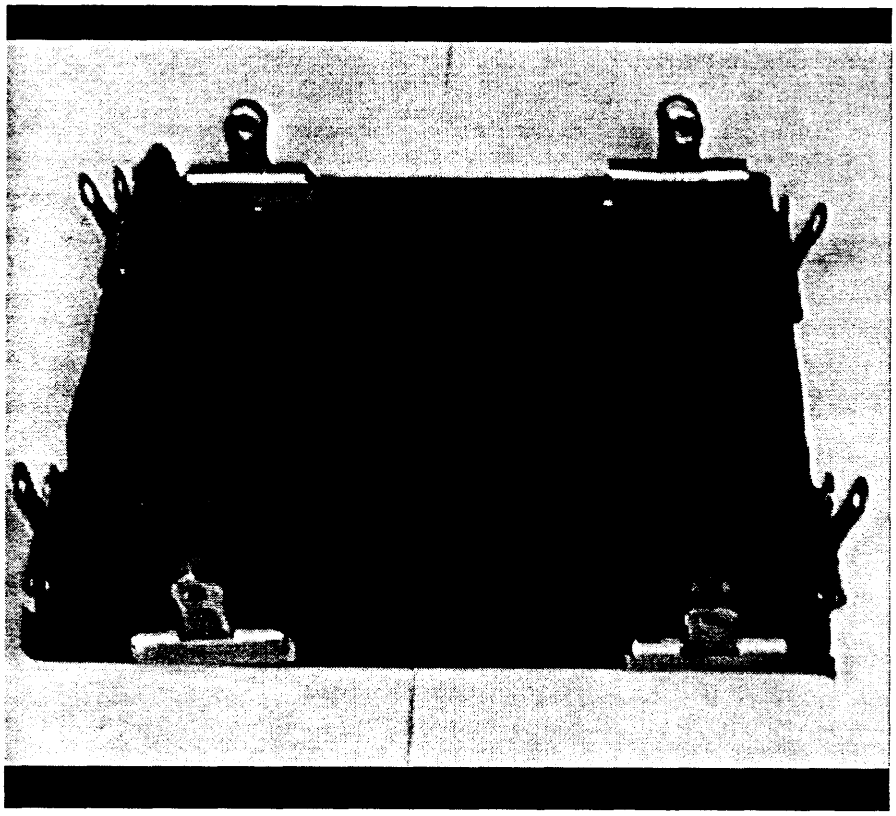
Fires involving ignition of the dust cover have also been identified in the fire data. The dust cover is the outermost material underneath the chair. The dust cover test evaluates fire performance in a horizontal test geometry.

The dust cover mock-up, shown in Figure 3, also consists of a square metal frame in which a dust cover specimen is placed. The dust cover specimen is tested by itself since there is substantial variation in furniture constructions; some products may have no combustible material above the dust cover. The primary intent of the Dust Cover Test is to ensure that materials used as dust cover fabrics or directly above dust covers do not support combustion when exposed to a small open flame source.

The General Requirements in the draft standard limit the allowable combustion time and flame spread of the dust cover mock-up samples. Some dust cover materials tend to melt away or split and expose interior materials when subjected to a small open flame. Interior materials within 1 inch above passing dust cover materials that are exposed if the dust cover melts away or splits, must also pass the Dust Cover Test. Staff believes that exposed interior materials within 1 inch above the dust cover may ignite from exposure to a small open flame source and involve the entire upholstered item. Therefore, interior materials should be resistant to small open flame ignition when used with dust covers that tend to melt away or split when exposed to a small open flame. These requirements are intended to lessen the likelihood of fires originating in the dust cover location from spreading and involving the entire finished item. Details on the selection of requirements and acceptance criteria are discussed later in this report.

Laboratory testing[4] has demonstrated that the technology is available to meet the requirements of the Dust Cover Test. These include the use of naturally flame resistant fabrics, chemical flame retardant fabrics treatments, and use of fire resistant barriers. Either one or combination of these technologies can be used to meet the draft standard.

Figure 3: Dust Cover Mock-up



4.3 Ignition Source

The ignition source is a butane diffusion flame intended to represent a small open flame source such as a match, cigarette lighter, or candle flame that may be present in residences. These types of ignition sources were identified in the Field Study[2] as the primary small open flame ignition sources.

The burner tube consists of a stainless steel tube with an outside diameter of approximately 8.0 mm and a wall thickness of 1.0 mm. The gas supply system consists of a pressure gage, flowmeter, fine control valve, and cylinder regulator providing an outlet pressure of 27.5 mbar (0.4 psi). The flow meter supplies butane gas at a constant rate of 45 ml/min at 25° C. Under the specified conditions, the flame height is approximately 35 mm.

Laboratory testing[5] has shown that the heat flux of the butane test flame is approximately 164 kW/ m^2. Comparisons between this test flame and other small open flame ignitions sources were made and are outlined in the Table 1.

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[5] Memorandum to Dale Ray from John Murphy and Larry Mulligan "Heat Flux and Temperature Measurements of 35 mm Butane Flame, Cigarette Lighters, Candles, and Matches", June 13, 1997.

As can be seen from the table below, the burner assembly produces a slightly higher amount of energy than can be expected from typical small open flame ignition sources. When characterizing the heat flux at different locations of the test flame, a second smaller diameter heat flux gage was used in addition to the heat flux gage used with the typical ignition sources. The smaller diameter gage measured values higher than the larger diameter gage. Therefore, in order to compare the heat flux produced by the test flame to typical ignition sources, only data from the larger diameter heat flux gage were used.

The heat output provides approximately 6 percent higher heat flux than cigarette lighters. Staff feels that the test flame is reasonable since it is similar to other small open flame ignition sources and variable times from sources such as candles and cigarette lighters can account for any differences.

Table 1: Comparison of Heat Fluxes of Typical Furniture Ignition Sources

OPEN FLAME SOURCE	HEAT FLUX (kW)/m^2	MAX. TEMP (C)
Kitchen Match	135	554
Cigarette Lighter	155	651
Tapered Candle	143	570
Votive Candle	124	560
Methanamine Pill	134	560
Test Flame	164	751

The draft standard requires the tip of the flame to be impinged on the dust cover specimen since the temperatures near the tip of the butane test flame are greatest in this location as found from laboratory testing.[5]

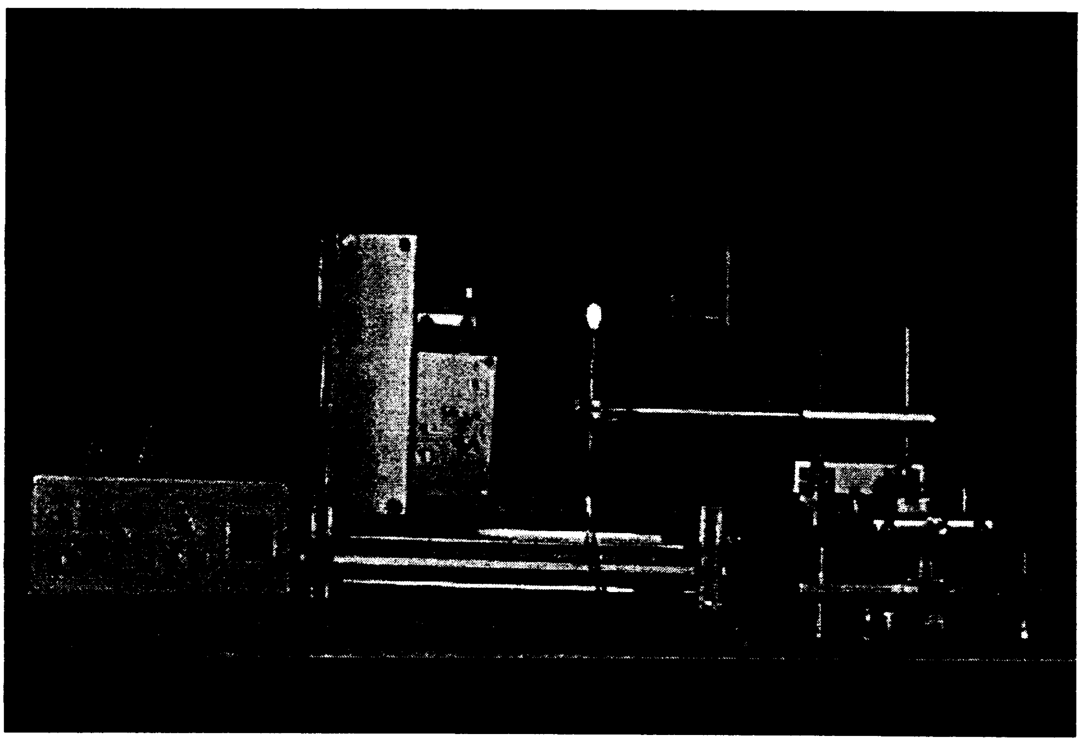
Table 2: Average 35 mm Butane Flame Temperatures

HEIGHT ABOVE BURNER TUBE	LEFT THERMOCOUPLE (C)	CENTER THERMOCOUPLE (C)	RIGHT THERMOCOUPLE (C)
10	587 ± 5	492 ± 5	540 ± 6
15	610 ± 40	550 ± 20	570 ± 30
20	590 ± 20	520 ± 20	540± 30
25	650 ± 60	550 ± 60	570 ± 70
30	660 ± 50	720 ± 10	720 ± 20
35	650 ± 50	710 ± 40	660 ± 80
40	670 ± 30	690 ± 10	630 ± 40
45	580 ± 60	640 ± 60	580± 70
50	560 ± 40	580 ± 60	500 ± 100

4.4 Flammability Test Fixture

A Flammability Test Fixture, shown in Figure 4, was developed to provide an automated test apparatus capable of delivering the test flame to the specimen in a repeatable and reproducible manner. The major components of the test fixture are the actuator, the mock-up assembly, and the control box. The actuator is a mechanical assembly that uses an electric linear drive to deliver the flame to the test specimen. The mock-up assembly consists of the framework that holds the two mock-ups in position. Finally, the control system contains functions to start the test and adjust the flame exposure time. Engineering Shop drawings of the Flammability Test Fixture are provided in the Appendix of the draft standard. For more detailed description of the Flammability Test Fixture refer to the "Operation Guide."

Figure 4: Furniture Flammability Fixture



[6] Furniture Flammability Operations Manual, June 1997

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4.5 Flame Exposure Time

The flame exposure time is a critical element of the test procedure that impacts the performance of the specimen. CPSC staff has chosen a **20 second** flame exposure time for the draft standard. The 20 second flame exposure time is based on (1) laboratory experiments which support that a 20 second exposure time differentiates between fabrics which readily ignite and sustain combustion, from fabrics which are more ignition resistant and (2) child fire play information which suggests that the focused, intentional behavior is needed to maintain a small open flame source in one location for more than 20 seconds.

CPSC laboratory testing[4] was conducted to characterize flammability performance of various upholstery fabrics using the seating area mock-up when tested[4] with a variety of flame impingement times ranging from 5 to 25 seconds. These tests show that most conventional upholstery fabrics readily ignited when exposed to the test flame for up to 20 seconds and continued to burn until the specimens were extinguished by test personnel. Therefore, the 20 second flame exposure is a good line of demarcation between fabrics which readily ignite and sustain combustion, from those which are more resistant to ignition or self extinguish when exposed to small open flame sources.

The 20 second flame exposure time is also used in the BS 5852 Standard, Part 2 Match Flame Test. The 20 second flame exposure time in BS 5852 is based on experimental work[7] conducted in the U.K. to characterize burn times of matches. In the U.K. study, various type of matches were tested with 15 composites in 6 different orientations using the BS 5852 type rig. The study concluded that 20 seconds was within the upper 85% of match burn times.

Laboratory experiments[8] were conducted by CPSC staff to characterize the burn times of typical small open flame ignition sources including matches and cigarette lighters. The results of the CPSC experiments indicate that there is extreme variability in match burn times depending on factors such as the type, orientation, and moisture content of matches. The average burn times ranged from 10 to 57 seconds. Cigarette lighters exhibited burn times which ranged from 200 to 960 seconds. Based on the results of CPSC's evaluation of small open flame ignition sources, flame exposure time in the draft standard cannot be based on experimental measure of flame duration alone, due to the wide variability of results.

The draft standard is intended to address flame exposure from child play and inadvertent contact, but not intentional acts to initiate a fire. The incident data[2] indicate the most frequent probable cause of upholstered furniture small open flame ignited fires is fire play by young children. Fire play is defined as a playful activity with no significant motivation toward fire setting behavior[9]. There are some motor and cognitive challenges for a young child to maintain a flame at a specific position unintentionally for 20 seconds. Therefore, the child who engages in this focused behavior is persistent beyond that which is typical of mere fire play, and represents an intentional act.

Although typical small open flame ignition sources may be capable of burning longer than 20 seconds, the behavior expected in child play and other inadvertent or accidental scenarios suggests that a 20 second flame exposure time would be reasonable for the draft standard. Also, testing of upholstery fabrics indicates that 20 seconds represents a demarcation point in fabric performance, and further supports selecting the 20 second exposure time.

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[7] "Standard Flaming Ignition Sources for Upholstered Composites, Furniture and Bed Assembly Tests", K.T. Paul, Journal of Fire Sciences.
[8] Memorandum to Dale Ray from John Murphy and R. Khanna "Match Burn Times, November 9, 1995.
[9] "Abilities of Young Children to Operate Butane Cigarette Lights", Comsis Corporation, March, 1988.

5.0 ACCEPTANCE CRITERIA

The performance requirements set forth in the draft standard are intended to reduce the societal impact of small open flame upholstered furniture fires. The General Requirements in the draft standard calls for the cessation of combustion (flaming, smoldering, etc.) and limit the flame progression on the test specimen within 2 minutes of flame removal following a 20 second flame exposure. Staff feels that 2 minutes allowable combustion time is appropriate to assess the propensity of furniture materials to self extinguish once combustion of the samples has begun. Any form of combustion that persists beyond 2 minutes can result in the transition to full involvement of the upholstered item and result in serious life safety hazard by involving other nearby combustible items. The goal of this approach is to prevent sustained combustion of upholstered furniture.

The staff decisions for the requirements of the draft standard are based on a review of existing furniture flammability standards, an analysis of current methods in furniture flammability technology, a review of field incidents, and a comprehensive testing program. After a review of the existing furniture flammability standards, staff concluded that the performance requirements set forth in BS 5852 which essentially require the cessation of any form of combustion on samples within 2 minutes after flame removal, would be most effective in reducing the fire hazard associated with upholstered furniture.

To assist in the development of the draft standard, staff assessed whether current technology available to the industry complies with the draft standard by conducting a series of laboratory studies described in this report and through discussions with textile product finishers. Staff concludes that current technology is available to the industry to meet the requirements of a small open flame standard. These include the use of naturally flame retardant fibers, flame retardant chemical treatments and backcoatings, and the use of some types fire blockers between the fabric and filling materials. Either one or a combination of current techniques can be used to meet the performance requirements set forth in the draft standard.

Staff conducted a series of laboratory tests[4] to confirm that the requirements set forth in the draft standard provide an improved level of safety from small open flame ignition of furniture. Mock-ups representing upholstery fabrics used in the current residential furniture market afforded little or no resistance to small open flame ignition. Once ignited, they continued to burn readily until they were completely consumed. Mock-ups containing one of the available flame resistant technologies demonstrated improved performance. For these samples, most ignited but self extinguished after the test flame was removed. The flame progression in the test specimens was a concern to staff as rapid flame progression in a full scale upholstered item may result in full involvement of the furniture item or ignition of nearby combustibles. To address this hazard, the draft standard requires that the flame progression must not reach the edge of the specimens. Staff concluded that the best performance measure for the hazard criteria was to limit the allowable combustion time and flame progression of the test specimen. The furniture industry could readily incorporate one or more of the available flame retardant technologies to meet the draft standard requirements.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: June 17, 1997

TO: Dale Ray
Project Manager
Directorate for Economic Analysis

Through: Andrew G. Ulsamer, Ph.D., AGU
Associate Executive Director,
Directorate for Laboratory Sciences

FROM: John Murphy, JRM
Mechanical Engineer,
Directorate for Engineering Sciences
for Larry Mulligan, AGU
General Engineer,
Directorate for Laboratory Sciences

SUBJECT: Comparative heat flux and temperature measurements for various open flame sources.

INTRODUCTION/BACKGROUND

The ignition source for the CPSC draft standard is a butane diffusion flame with a measured height of 35 mm (1.4 in). To characterize the 35mm butane flame, heat energy output and temperature profiles were measured using heat flux transducers and thermocouples. Comparisons were also made between the heat energy output and the temperature of the butane flame and other common small open flame ignition sources such as cigarette lighters, candles, matches, and methenamine tablets (A standard flame source for carpet testing). This memo reports the results of this study.

Method

Heat Flux

Two different models of Schmidt-Boelter thermopile heat flux transducers were used to take the heat flux measurements. One was a model 64-10sb-36-20K with a smooth body and flange. The diameter of the copper body on this transducer is about 25 mm (1 in.) The other one was a model 8-1.5-10SB-4-0-36-20680K. The body of this transducer is 13 mm(0.5 in) in diameter. The lower end of the transducer is reduced in diameter to 3 mm (0.125 in) forming a probe that is 38 mm (1.5 in) long. Both transducers are water cooled with a K-type thermocouple to monitor the body temperature of the transducer. The transducers have a rated capacity of 113.6 kilowatts/meter^2 (10 Btu/ft^{2}sec). Readings can be taken from zero to 150% of the rated capacity.

The heat flux transducers were mounted so that the measurement surface of the transducer was horizontal and positioned over the flame. Water was circulated through the transducers during testing. The temperature of the water was controlled so that the body temperature of the transducer was maintained at 50 ± 2°C. This was done to avoid condensation on the sensing surface during measurements.

Heat flux measurements were performed on a tapered candle, a votive candle, a cigarette lighter, a methenamine tablet, and kitchen matches. These measurements were taken with the transducer located at the tip of the flame. Other measurements were made at 4 mm increments along the central axis of the burner tube.

The transducers were cleaned with a moistened tissue in-between readings to prevent a soot build-up caused by being placed over the flame. The measurements were taken with the transducer suspended from a ring stand without any surrounding structure.

Flame Temperature

The temperature of the butane flame was measured at various locations in the flame. This required precise positioning of the thermocouple. To achieve this, three K-type thermocouple (enclosed for rigidity in ceramic tubes) were fitted into a machined holding block. This block was then securely mounted, via a matched machined spline and groove onto a Mitutoyo Digimatic Height Gage. The thermocouple were arranged so that the two outermost were aligned with the outside edge of the burner tube, the third was located above the center of the burner tube. Measurements were taken every five millimeters and repeated several times on different days to assess the distribution of temperatures within the flame.

Results/Discussion

Heat flux data for several common flame sources are listed in Table I. Measurements were taken using the small diameter heat flux transducer positioned at the tip of the flame. The 35 mm butane flame heat flux is closest to that for the cigarette lighter but is somewhat greater than those for the other flame sources. All flame sources are reasonably similar.

The heat flux profile of the 35 mm butane flame is presented in Table II. The geometry of the heat flux transducer had a large influence on the measured values. The large diameter transducer suspended in a ring stand measured a heat flux that was one half the heat flux measured by the small diameter transducer. It is known that the measurement procedures such as the orientation of the transducers, the size of the sensing surface, the mounting used to support the transducers, and especially the geometry of the test setup significantly affects the final readings, To determine the precise reason for this difference would require additional work. The data show that the presence of the heat transducer in the flame disturbs the properties of the flame. The measured heat flux is different when the transducer impinges into the flame as opposed to when the transducer is near the tip of the flame. As a result, the heat flux of the disturbed flame can be very different from the heat flux of an undisturbed flame or of the flame during testing. The highest heat fluxes occurred within four millimeters on either side of the flame tip.

The average flame temperatures and the standard deviations are shown in Table III. The highest temperatures of the butane flame were measured at 30 mm above the tube. The temperatures were only slightly lower at 35 or 40 mm above the burner tube. Maximum temperatures at heights below 30 mm are at the outer positions, whereas at greater heights, the maximum temperature is along the vertical center line of the flame. There was clearly some flame movement as shown by the changes in temperature observed.

The tube was not mounted in the interlaboratory test fixture, which might shield the flame from some air currents.

Temperature measurements of a butane cigarette lighter are shown in Table IV. As with the heat flux measurements the cigarette lighter temperatures were somewhat lower than for the butane flame. The flame height is also somewhat lower than for the butane flame. The flame height is also somewhat lower than the 35 mm butane flame as judged by the temperature readings.

Table 1 measurements of some common household ignition sources

Item	**Heat Flux as measured by small diameter transducer in ring stand kilowatt/meter^2**
8" Tapered Candle	143 ± 1
Votive Candle	124 ± 6
Cigarette Lighter	155 ± 2
Methenamine Tablet	134 ± 9
Match	135 ± 19
35 mm Butane Flame	164 ± 3

Table II Measurements of Heat Flux at Different Heights in 35mm Butane Flame

Height above Burner Tube (millimeters)	Heat Flux as measured by large diameter transducer in ring stand (kilowatt/meter2)	Heat Flux as measured by small diameter transducer in ring stand (kilowatt/meter2)
7	3 ± 1	
11	11 ± 1	5.7
15	25 ± 1	45 ± 3
19	41 ± 1	61 ± 3
23	54 ± 1	76 ± 7
27	65 ± 2	98 ± 10
31	76 ± 0	132 ± 10
35	**80 ± 1**	**164 ± 3**
39	73 ± 2	164 ± 3
43	65 ± 2	129 ± 8
47	65 ± 1	112 ± 11

Table III Average 35 mm Butane Flame Temperatures

Height above Vertical Tube (mm)	Left Thermocouple Temperature (C)	Center Thermocouple Temperature (C)	Right Thermocouple Temperature (C)
10	587±5	492±5	540±6
15	610±40	550±20	570±30
20	590±20	520±20	540±30
25	650±60	550±60	570±70
30	660±50	720±10	720±20
35	650±50	710±40	660±80
40	670±30	690±10	630±40
45	580±60	640±60	580±70
50	560±40	580±60	500±100

Table IV Flame Temperature of Cigarette Lighter

Height above Vertical Tube (mm)	Left Thermocouple Temperature (C)	Center Thermocouple Temperature (C)	Right Thermocouple Temperature (C)
5	367	435	574
10	480	533	628
15	599	583	642
20	651	605	649
25	619	567	624
30	558	489	555

Conclusions

Measurements of the heat flux of several common household ignition sources such as candles, cigarette lighters, and kitchen matches, show some variation but are reasonably similar. The heat flux values of the household sources are also reasonably similar to those of the 35 mm butane flame.

The maximum heat flux, for all ignition sources, generally occurred near the tip of the flame, as expected, but allowed some flexibility for flame placement with little effect on heat flux.

Measurement of the temperature of a cigarette lighter and the 35 mm butane flame indicates that both have reasonably similar maximum temperatures. The maximum temperature of the 35 mm butane flame is near the tip of the flame but allows some flexibility in placement of the flame. Both heat flux and temperature data clearly indicate that the tip of the flame is preferable to allowing the flame to impact the fabric closer to the burner tube.

cc:
Rohit Khanna